

EVALUATION OF n + 52Cr CROSS SECTIONS FOR THE ENERGY
RANGE 1.0E-11 to 150 MeV

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This evaluation provides a complete representation of the nuclear data needed for transport, damage, heating, radioactivity, and shielding applications over the incident neutron energy range from 1.0E-11 to 150 MeV. The discussion here is divided into the region below and above 20 MeV.

INCIDENT NEUTRON ENERGIES < 20 MeV

Below 20 MeV the evaluation is based completely on the ENDF/B-VI (Revision 1) evaluation by D. Hetrick, D. Larson, N. Larson, and C. Y. Fu.

INCIDENT NEUTRON ENERGIES > 20 MeV

The ENDF/B-VI Release 2 evaluation extends to 20 MeV and includes cross sections and energy-angle data for all significant reactions. The present evaluation utilizes a more compact composite reaction spectrum representation above 20 MeV in order to reduce the length of the file. No essential data for applications is lost with this representation.

The evaluation above 20 MeV utilizes MF=6, MT=5 to represent all reaction data. Production cross sections and emission spectra are given for neutrons, protons, deuterons, tritons, alpha particles, gamma rays, and all residual nuclides produced ($A>5$) in the reaction chains. To summarize, the ENDF sections with non-zero data above $En = 20$ MeV are:

- MF=3 MT= 1 Total Cross Section
- MT= 2 Elastic Scattering Cross Section
- MT= 3 Nonelastic Cross Section
- MT= 5 Sum of Binary (n,n') and (n,x) Reactions

- MF=4 MT= 2 Elastic Angular Distributions

- MF=6 MT= 5 Production Cross Sections and Energy-Angle Distributions for Emission Neutrons, Protons, Deuterons, Tritons, and Alphas; and Angle-Integrated Spectra for Gamma Rays and Residual Nuclei That Are Stable Against Particle Emission

The evaluation is based on nuclear model calculations that have been benchmarked to experimental data, especially for n + Cr52 and p + Cr52 reactions (Ch97). We use the GNASH code system (Yo92), which utilizes Hauser-Feshbach statistical, preequilibrium and direct-reaction theories. Spherical optical model calculations are used to obtain particle transmission coefficients for the Hauser-Feshbach calculations, as well as for the elastic neutron angular distributions.

Cross sections and spectra for producing individual residual nuclei are included for reactions. The energy-angle-correlations for all outgoing particles are based on Kalbach systematics (Ka88).

A model was developed to calculate the energy distributions of

all recoil nuclei in the GNASH calculations (Ch96). The recoil energy distributions are represented in the laboratory system in MT=5, MF=6, and are given as isotropic in the lab system. All other data in MT=5, MF=6 are given in the center-of-mass system. This method of representation utilizes the LCT=3 option approved at the November, 1996, CSEWG meeting.

Preequilibrium corrections were performed in the course of the GNASH calculations using the exciton model of Kalbach (Ka77, Ka85), validated by comparison with calculations using Feshbach, Kerman, Koonin (FKK) theory [Ch93]. Discrete level data from nuclear data sheets were matched to continuum level densities using the formulation of Ignatyuk et al. (Ig75) and pairing and shell parameters from the Cook (Co67) analysis. Neutron and charged-particle transmission coefficients were obtained from the optical potentials, as discussed below. Gamma-ray transmission coefficients were calculated using the Kopecky-Uhl model (Ko90).

SOME Cr-SPECIFIC INFORMATION CONCERNING THE EVAL.

The neutron total cross section was evaluated at grid energy points by using the least-squares code GMA (Po81) taking account of the new data measured by Dietrich et al. for natural Cr (Di97). The results were transformed to the Cr-52 cross section according to $A^{*(2/3)}$ law, i.e., by multiplying a factor of 0.999305.

The evaluated total cross section data (present result from 20 to 250 MeV, and ENDF/B-VI value below 20 MeV), s-wave strength function (Mu81), and elastic scattering angular distribution data (Ki74, Ol87) were used to obtain the neutron optical potential parameters. The parameter estimation was carried out based on Bayesian approach (Sm91), where ECIS95 code was used for the optical model calculation. We have employed the energy dependence of the optical potential similar to Delaroche's work (De89). Total of 18 parameters concerning the central potential were estimated. Presently obtained potential was used for the calculation of neutron transmission coefficients and DWBA cross sections in the entire energy region.

For proton channel, a combination of 2 potentials were used :

below 40 MeV : Becchetti-Greenlees

above 40 MeV : Madland medium energy potential

The proton reaction cross section and transmission coefficients below 40 MeV were multiplied by a factor of 0.845 to make the agreement with the measured proton reaction cross section (Ca96) better, and also to make the connection to higher energy values smoothly.

For deuterons, the Lohr-Haeberli global potential was used; for alpha particles the Moyen potential (MacFadden-Satchler) was used; and for tritons the Becchetti-Greenlees potential was used. The He-3 channel was ignored.

The direct collective inelastic scattering to the following levels in Cr-52 was considered by the DWBA-mode calculation of ECIS95:

Jpi Ex(MeV) Deformation length

2+	1.434	0.87
4+	2.369	0.33

0+	2.647	0.095
4+	2.768	0.30
2+	2.965	0.08
6+	3.114	0.35
2+	3.162	0.27
4+	3.415	0.13
2+	3.772	0.28
4+	4.040	0.16
3-	4.563	0.61
4+	4.630	0.36
0+	4.738	0.145
4+	4.951	0.20
4+	5.095	0.15
4+	5.425	0.32
4+	5.541	0.074
2+	5.661	0.095
3-	5.873	0.082
3-	5.996	0.087
2+	6.055	0.13
2+	6.143	0.07
2+	6.175	0.21
2+	6.493	0.21
3-	6.580	0.34
3-	6.786	0.26
2+	6.810	0.22
5-	6.871	0.16
3-	6.993	0.18
3-	7.080	0.34
4+	7.140	0.14
2+	7.217	0.10
4+	7.278	0.13
2+	7.344	0.074
5-	7.376	0.11
3-	7.409	0.091
3-	7.482	0.13
3-	7.585	0.074
3-	7.738	0.26
3-	7.823	0.12
4+	7.848	0.11
4+	7.893	0.12
3-	7.967	0.095
2+	8.022	0.10
3-	8.089	0.091
3-	8.281	0.15
3-	8.457	0.13
3-	8.505	0.10
3-	8.679	0.10
3-	8.782	0.10
3-	8.778	0.13
3-	9.440	0.095

These data were retrieved from the literature (Ju94).

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 1 = PROJECTILE 1000Z+A

Nonelastic, elastic, and Production cross sections for A<5 ejectiles in barns:

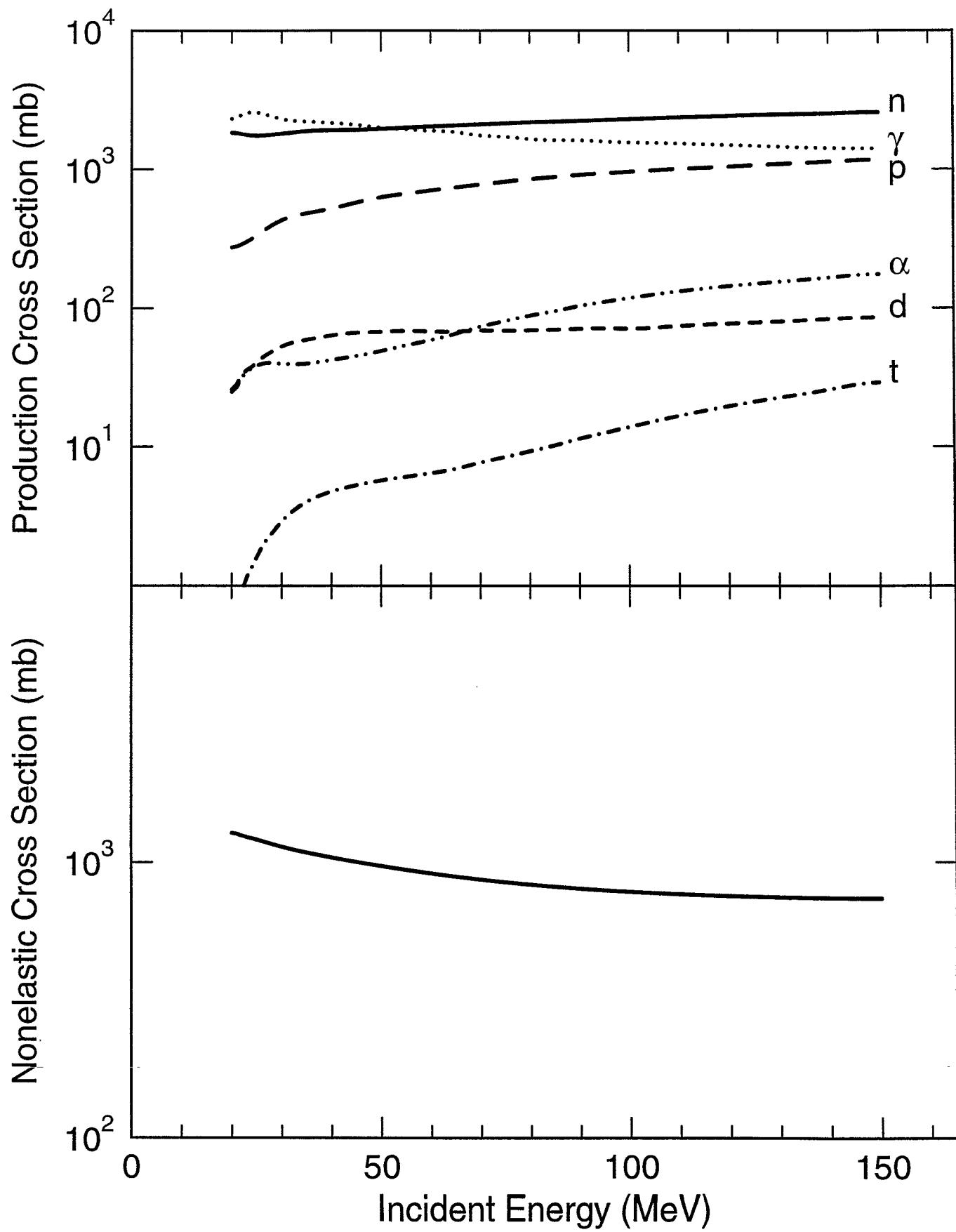
Energy	nonelas	elastic	neutron	proton	deuteron	triton	helium3	alpha	gamma
2.000E+01	1.279E+00	9.163E-01	1.835E+00	2.751E-01	2.588E-02	4.586E-04	0.000E+00	2.480E-02	2.315E+00
2.200E+01	1.250E+00	9.350E-01	1.798E+00	2.901E-01	3.265E-02	8.735E-04	0.000E+00	3.146E-02	2.470E+00
2.400E+01	1.222E+00	9.915E-01	1.754E+00	3.174E-01	3.775E-02	1.353E-03	0.000E+00	3.679E-02	2.587E+00
2.600E+01	1.194E+00	1.042E+00	1.752E+00	3.553E-01	4.347E-02	1.890E-03	0.000E+00	3.968E-02	2.527E+00
2.800E+01	1.165E+00	1.109E+00	1.782E+00	3.967E-01	4.847E-02	2.382E-03	0.000E+00	4.025E-02	2.412E+00
3.000E+01	1.138E+00	1.171E+00	1.809E+00	4.328E-01	5.292E-02	2.905E-03	0.000E+00	3.971E-02	2.306E+00
3.500E+01	1.084E+00	1.312E+00	1.886E+00	4.846E-01	5.915E-02	4.013E-03	0.000E+00	3.980E-02	2.210E+00
4.000E+01	1.041E+00	1.416E+00	1.920E+00	5.247E-01	6.365E-02	4.764E-03	0.000E+00	4.233E-02	2.159E+00
4.500E+01	1.002E+00	1.477E+00	1.929E+00	5.794E-01	6.665E-02	5.287E-03	0.000E+00	4.508E-02	2.089E+00
5.000E+01	9.685E-01	1.499E+00	1.959E+00	6.318E-01	6.761E-02	5.722E-03	0.000E+00	4.910E-02	1.990E+00
5.500E+01	9.382E-01	1.492E+00	2.000E+00	6.703E-01	6.867E-02	6.081E-03	0.000E+00	5.383E-02	1.947E+00
6.000E+01	9.110E-01	1.462E+00	2.036E+00	7.069E-01	6.787E-02	6.446E-03	0.000E+00	5.880E-02	1.902E+00
6.500E+01	8.866E-01	1.413E+00	2.075E+00	7.436E-01	6.773E-02	6.934E-03	0.000E+00	6.532E-02	1.860E+00
7.000E+01	8.649E-01	1.352E+00	2.110E+00	7.803E-01	6.905E-02	7.695E-03	0.000E+00	7.353E-02	1.756E+00
7.500E+01	8.458E-01	1.291E+00	2.148E+00	8.159E-01	6.864E-02	8.435E-03	0.000E+00	8.059E-02	1.717E+00
8.000E+01	8.289E-01	1.219E+00	2.182E+00	8.497E-01	6.915E-02	9.260E-03	0.000E+00	8.813E-02	1.651E+00
8.500E+01	8.141E-01	1.145E+00	2.205E+00	8.800E-01	6.977E-02	1.019E-02	0.000E+00	9.503E-02	1.622E+00
9.000E+01	8.012E-01	1.076E+00	2.236E+00	9.100E-01	7.082E-02	1.139E-02	0.000E+00	1.035E-01	1.620E+00
9.500E+01	7.900E-01	1.002E+00	2.269E+00	9.347E-01	7.137E-02	1.253E-02	0.000E+00	1.105E-01	1.585E+00
1.000E+02	7.803E-01	9.385E-01	2.303E+00	9.584E-01	7.111E-02	1.377E-02	0.000E+00	1.177E-01	1.564E+00
1.100E+02	7.647E-01	8.141E-01	2.370E+00	1.005E+00	7.413E-02	1.662E-02	0.000E+00	1.318E-01	1.532E+00
1.200E+02	7.533E-01	7.045E-01	2.428E+00	1.043E+00	7.716E-02	1.954E-02	0.000E+00	1.439E-01	1.493E+00
1.300E+02	7.452E-01	6.093E-01	2.480E+00	1.087E+00	7.964E-02	2.245E-02	0.000E+00	1.544E-01	1.446E+00
1.400E+02	7.398E-01	5.334E-01	2.524E+00	1.130E+00	8.313E-02	2.576E-02	0.000E+00	1.654E-01	1.414E+00
1.500E+02	7.373E-01	4.654E-01	2.579E+00	1.167E+00	8.527E-02	2.899E-02	0.000E+00	1.746E-01	1.404E+00

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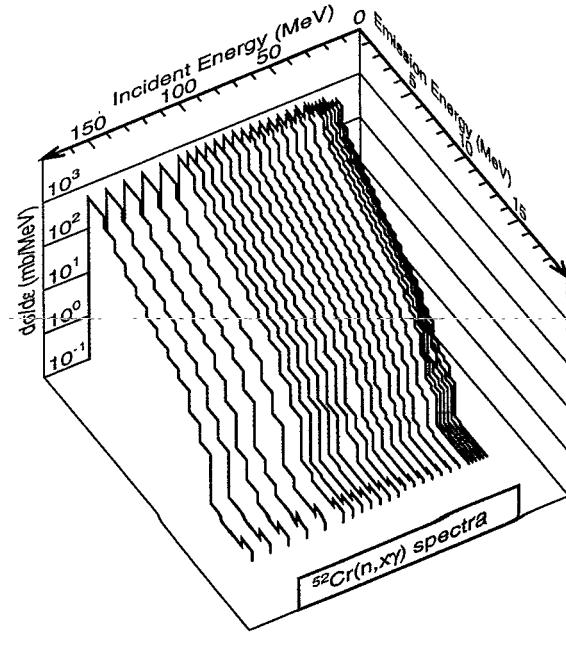
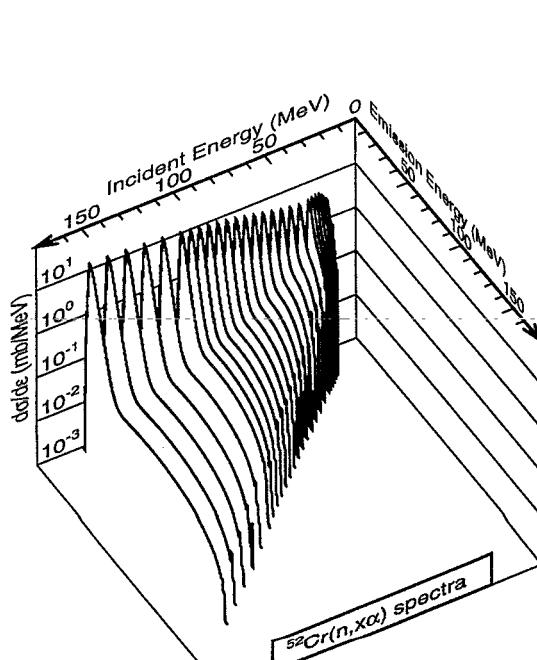
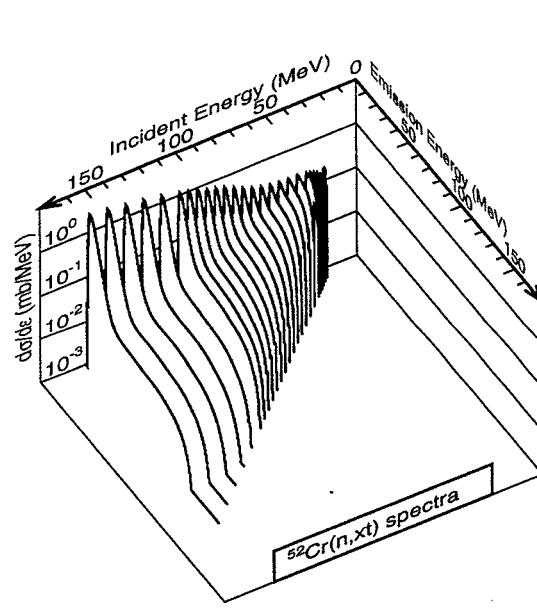
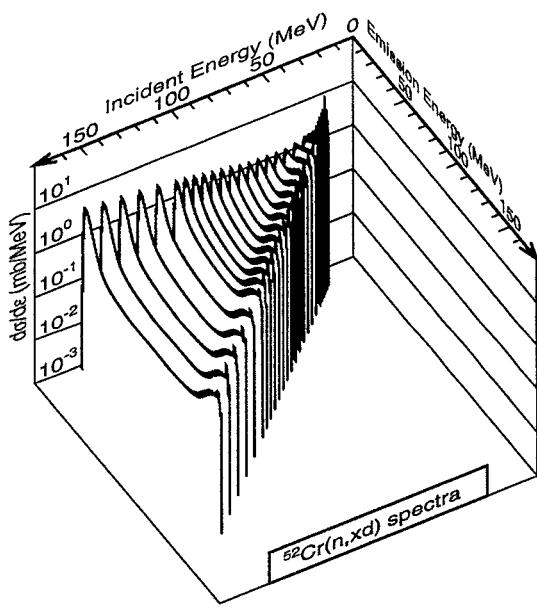
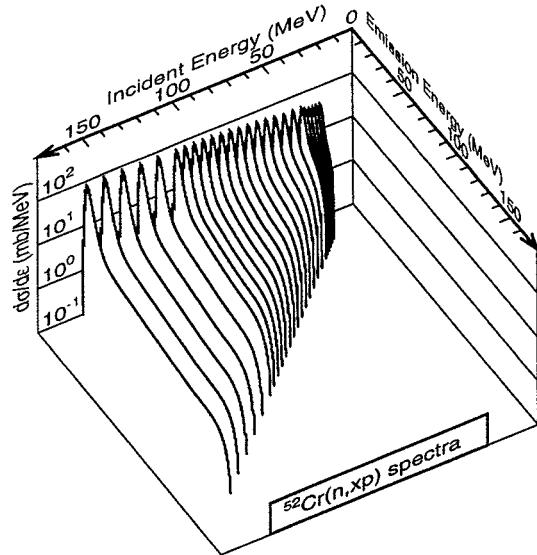
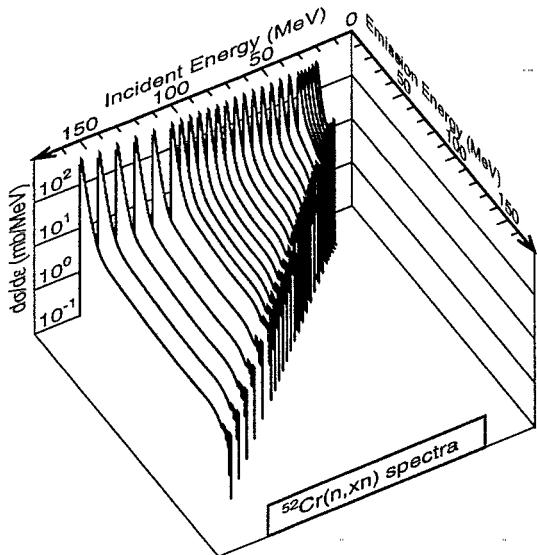
Kerma coefficients in units of f.Gy.m^2:

Energy	proton	deuteron	triton	helium3	alpha	non-rec	elas-rec	TOTAL
2.000E+01	2.987E-01	3.823E-02	3.929E-04	0.000E+00	4.111E-02	1.082E-01	2.651E-02	5.132E-01
2.200E+01	3.445E-01	5.551E-02	8.998E-04	0.000E+00	5.290E-02	1.152E-01	2.835E-02	5.973E-01
2.400E+01	3.975E-01	7.170E-02	1.600E-03	0.000E+00	6.329E-02	1.212E-01	3.017E-02	6.855E-01
2.600E+01	4.600E-01	9.184E-02	2.524E-03	0.000E+00	7.086E-02	1.260E-01	3.096E-02	7.821E-01
2.800E+01	5.299E-01	1.125E-01	3.485E-03	0.000E+00	7.473E-02	1.298E-01	3.168E-02	8.822E-01
3.000E+01	6.049E-01	1.338E-01	4.662E-03	0.000E+00	7.644E-02	1.333E-01	3.195E-02	9.851E-01
3.500E+01	7.924E-01	1.800E-01	7.805E-03	0.000E+00	8.145E-02	1.424E-01	3.162E-02	1.236E+00
4.000E+01	9.748E-01	2.296E-01	1.082E-02	0.000E+00	8.980E-02	1.508E-01	3.024E-02	1.486E+00
4.500E+01	1.165E+00	2.788E-01	1.362E-02	0.000E+00	9.817E-02	1.575E-01	2.840E-02	1.742E+00
5.000E+01	1.359E+00	3.175E-01	1.622E-02	0.000E+00	1.081E-01	1.637E-01	2.634E-02	1.991E+00
5.500E+01	1.548E+00	3.569E-01	1.857E-02	0.000E+00	1.194E-01	1.689E-01	2.425E-02	2.236E+00
6.000E+01	1.737E+00	3.812E-01	2.082E-02	0.000E+00	1.312E-01	1.730E-01	2.220E-02	2.465E+00
6.500E+01	1.923E+00	4.076E-01	2.296E-02	0.000E+00	1.456E-01	1.778E-01	2.021E-02	2.697E+00
7.000E+01	2.101E+00	4.446E-01	2.518E-02	0.000E+00	1.632E-01	1.835E-01	1.835E-02	2.935E+00
7.500E+01	2.287E+00	4.628E-01	2.733E-02	0.000E+00	1.789E-01	1.879E-01	1.671E-02	3.161E+00
8.000E+01	2.474E+00	4.894E-01	2.948E-02	0.000E+00	1.954E-01	1.913E-01	1.513E-02	3.394E+00
8.500E+01	2.658E+00	5.154E-01	3.168E-02	0.000E+00	2.112E-01	1.945E-01	1.368E-02	3.625E+00
9.000E+01	2.844E+00	5.399E-01	3.412E-02	0.000E+00	2.297E-01	1.983E-01	1.243E-02	3.858E+00
9.500E+01	3.037E+00	5.591E-01	3.643E-02	0.000E+00	2.460E-01	2.012E-01	1.122E-02	4.091E+00
1.000E+02	3.235E+00	5.628E-01	3.887E-02	0.000E+00	2.628E-01	2.030E-01	1.022E-02	4.313E+00
1.100E+02	3.623E+00	6.151E-01	4.396E-02	0.000E+00	2.964E-01	2.086E-01	8.465E-03	4.795E+00
1.200E+02	4.022E+00	6.675E-01	4.868E-02	0.000E+00	3.268E-01	2.132E-01	7.060E-03	5.285E+00
1.300E+02	4.440E+00	7.087E-01	5.273E-02	0.000E+00	3.544E-01	2.245E-01	5.935E-03	5.787E+00
1.400E+02	4.859E+00	7.575E-01	5.699E-02	0.000E+00	3.832E-01	2.384E-01	5.084E-03	6.301E+00
1.500E+02	5.316E+00	7.773E-01	6.121E-02	0.000E+00	4.092E-01	2.498E-01	4.371E-03	6.818E+00

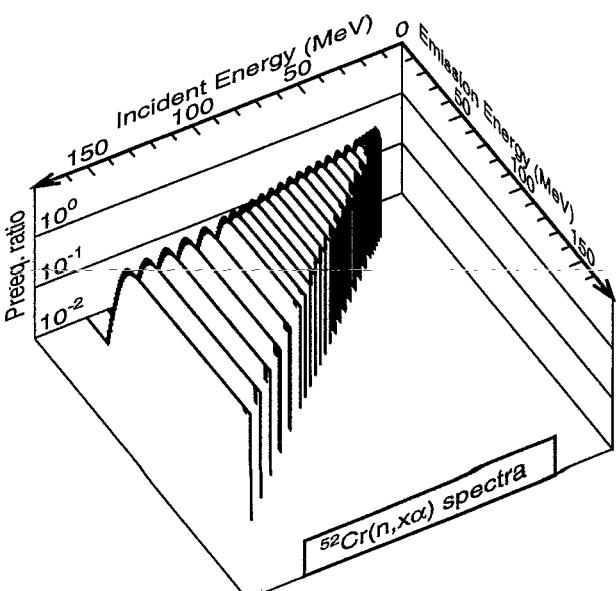
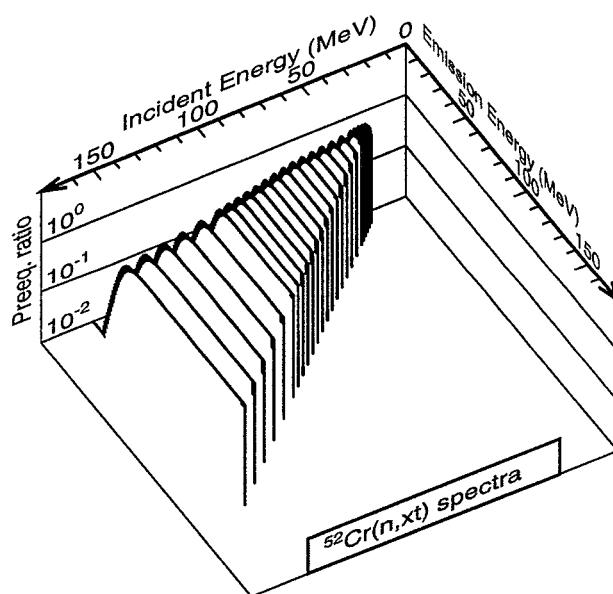
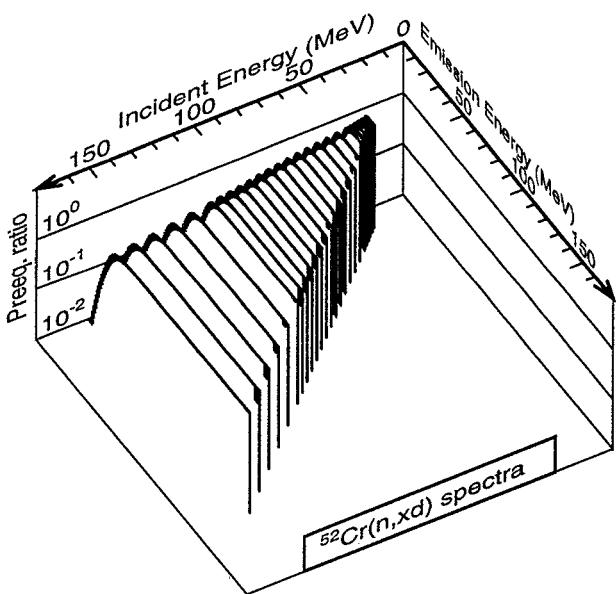
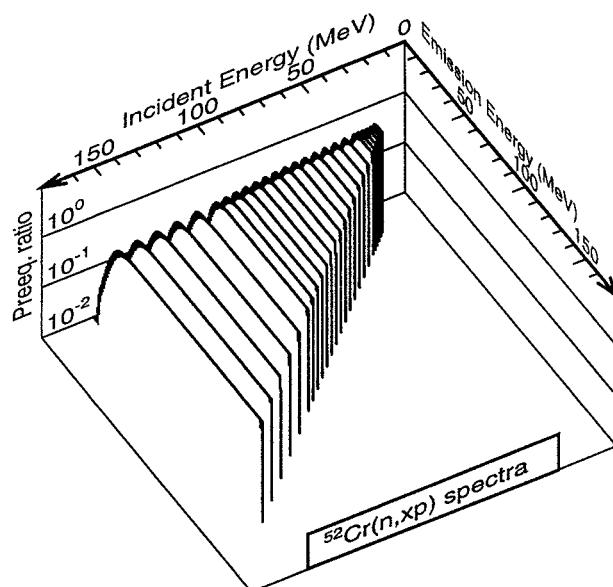
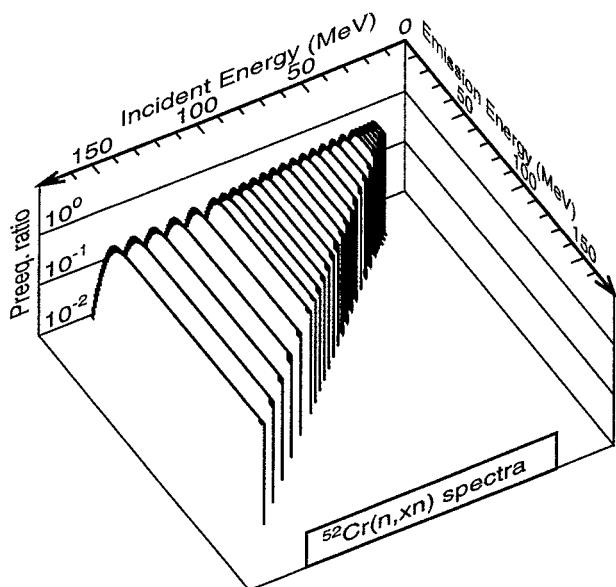
$n + {}^{52}\text{Cr}$ nonelastic and production cross sections



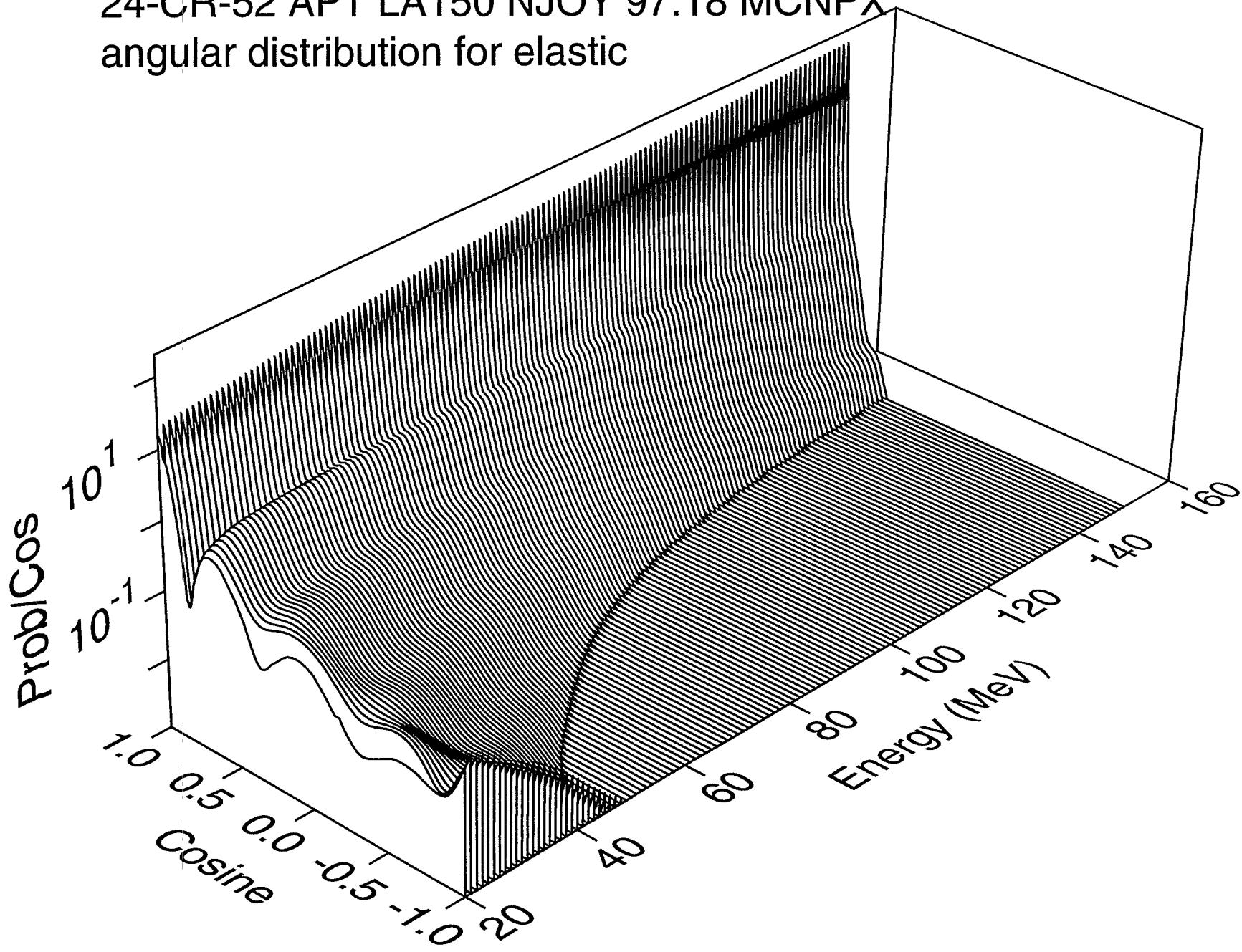
$n + {}^{52}\text{Cr}$ angle-integrated emission spectra



$n + {}^{52}\text{Cr}$ Kalbach preequilibrium ratios

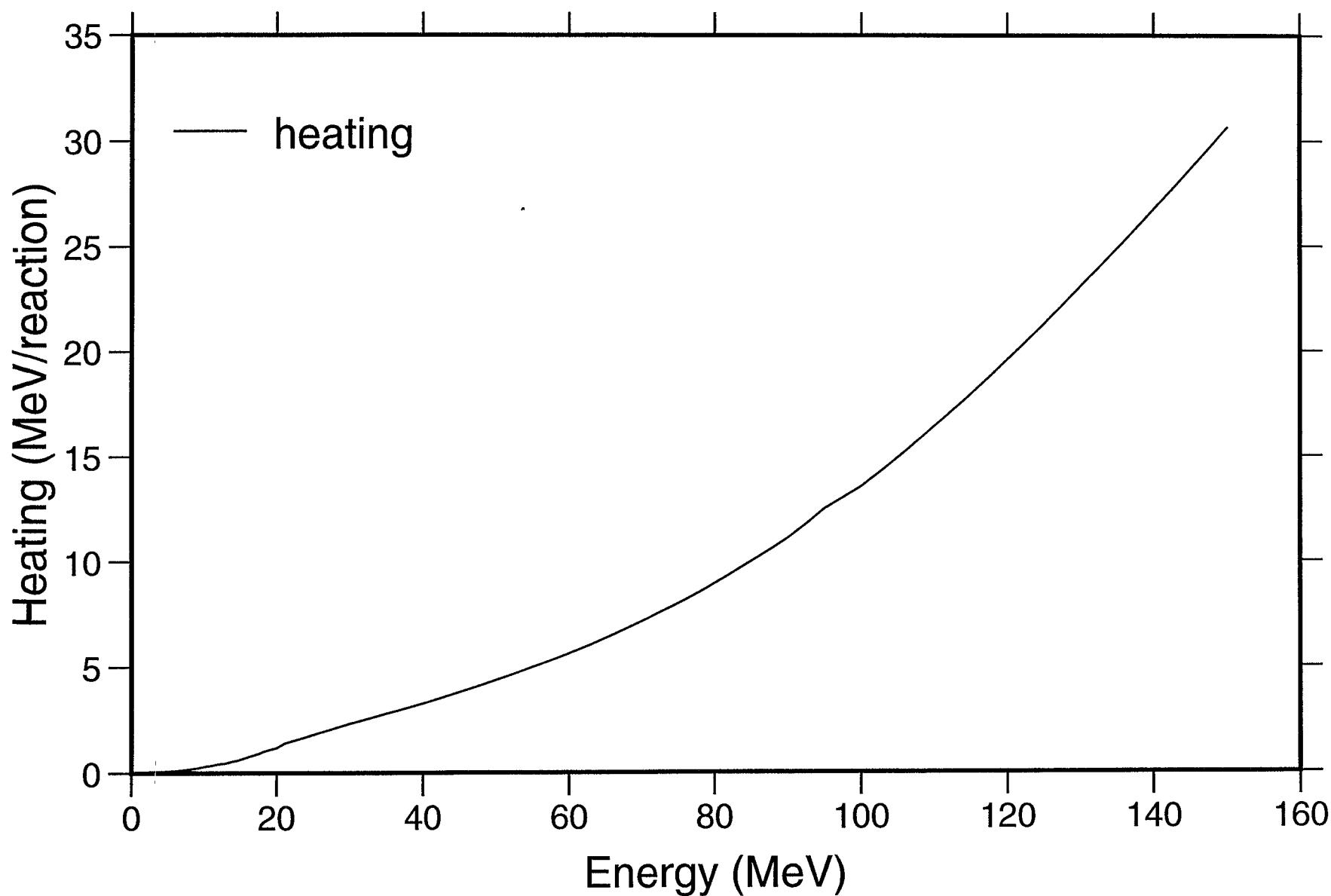


24-CR-52 APT LA150 NJOY 97.18 MCNPX
angular distribution for elastic



24-CR-52 APT LA150 NJOY 97.18 MCNPX

Heating



24-CR-52 APT LA150 NJOY 97.18 MCNPX

Damage

